

Rec'd PCT/PTO 04 MAR 2005

PCT IB 03 / 03745



Europäisches  
Patentamt

European  
Patent Office

Office européen  
des brevets 05 SEP 2003

REC'D 19 SEP 2003

WIPO PCT

Bescheinigung

Certificate

Attestation.

Die angehefteten Unterla-  
gen stimmen mit der  
ursprünglich eingereichten  
Fassung der auf dem näch-  
sten Blatt bezeichneten  
europäischen Patentanmel-  
dung überein.

The attached documents  
are exact copies of the  
European patent application  
described on the following  
page, as originally filed.

Les documents fixés à  
cette attestation sont  
conformes à la version  
initialement déposée de  
la demande de brevet  
européen spécifiée à la  
page suivante.

Patentanmeldung Nr. Patent application No. Demande de brevet n°

02078806.3

**PRIORITY DOCUMENT**  
SUBMITTED OR TRANSMITTED IN  
COMPLIANCE WITH  
RULE 17.1(a) OR (b)

Der Präsident des Europäischen Patentamts;  
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets  
p.o.

R C van Dijk

BEST AVAILABLE COPY



Anmeldung Nr:  
Application no.: 02078806.3  
Demande no:

Anmeldetag:  
Date of filing: 05.09.02  
Date de dépôt:

Anmelder/Applicant(s)/Demandeur(s):

Gambro Lundia AB  
Magistratsvägen 16  
22 643 Lund  
SUEDE

Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:  
(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.  
If no title is shown please refer to the description.  
Si aucun titre n'est indiqué se référer à la description.)

Controller and control method for a blood treatment equipment

In Anspruch genommene Priorität(en) / Priority(ies) claimed /Priorité(s)  
revendiquée(s)

Staat/Tag/Aktenzeichen/State/Date/File no./Pays/Date/Numéro de dépôt:

Internationale Patentklassifikation/International Patent Classification/  
Classification internationale des brevets:

A61M1/14

Am Anmeldetag benannte Vertragstaaten/Contracting states designated at date of  
filing/Etats contractants désignées lors du dépôt:

AT BE BG CH CY CZ DE DK EE ES FI FR GB GR IE IT LI LU MC NL PT SE SK TR

## Controller and control method for a blood treatment equipment.

### FIELD OF INVENTION

5 This invention relates to a controller and control method for a blood treatment equipment. The present invention relates also to a blood treatment equipment comprising said control apparatus.

More particularly, the invention is concerned with an  
10 apparatus, such as a programmable computer, capable of operating on a blood treatment equipment such as an hemodialysis equipment; the programmable controller is adapted to receive entries of prescribed and measured information and to generate one or more output signals  
15 In response thereto. In general the output signals are employed to control a variable operation performed by a dialysis equipment and hence automatically perform hemodialysis procedure control methods.

### 20 BACKGROUND OF THE INVENTION

As is for example explained in Gambro EP0330 892, it is of advantage to employ measured values of a patient's conditional values to control functional

aspects of hemodialysis equipments. In this fashion, the hemodialysis equipment may be controlled dependently of specific treatment requirements of a patient. An important parameter includes actual

5 ~~clearance or dialysance values (expressed herein as D~~  
in ml/min). The value D is representative of the clearance of a blood solute and may be employed to determine a total dialysis dosage value  $KT_t$  achieved after time  $T_t$ .

10

The approach presently followed is to obtain a measure of and to provide information related to a total dialysis dosage value delivered as time progresses during a hemodialysis treatment procedure. This measure and  
15 the information provided is essentially based on parameters which include:

a prescribed duration of the treatment procedure.

the blood flow rate

20 the choice of the hemodialyser

A combination of above parameters is employed to obtain a measure of the total dialysis dosage value  $KT_t$  delivered as an integral of mean measured

instantaneous clearance values measured after  
determined time increments, the dialysance of the  
chosen dialyser (which is an in vitro clearance value)  
and the effective treatment time. The effective  
5 treatment time is the time during which diffusive (and  
generally also convective) transfer of blood solutes  
across a semi-permeable membrane of a hemodialyser  
takes place.

10

The above procedure basically enables a measure to be  
made of the KT value delivered to a patient during a  
hemodialysis treatment procedure. This procedure,  
however, suffers from a number of drawbacks.  
15 Specifically, such factors as blood flow rate and  
effective treatment time which are relevant to clearance  
are prone to change or are difficult to follow during a  
hemodialysis treatment procedure. Furthermore, the  
dialysance or clearance capacity of hemodialyser  
20 products can change significantly during a hemodialysis  
treatment procedure time. Present day hemodialysis  
monitoring equipment and hemodialysis procedure  
methods may comprise means for assessing or  
measuring dialysis dosages delivered to a patient over

determined time increments, but no means are available for controlling the dialysis dosage value actually delivered to the patient within a prescribed treatment time.

---

5

It is an overall objective of the present invention to secure control over the actual total dialysis dosage delivered to a patient.

10

## SUMMARY OF THE INVENTION

15 Hemodialysis monitoring equipment of the invention is associated with or comprises a programmable controller adapted to receive entries of prescribed and measured information and to generate one or more control signals in response thereto. The controller is adapted to  
20 receive one or more entries of measured information measured during the course of a hemodialysis treatment procedure. The measured information is of such a nature that this can reflect one or more measures of dialysis dosages or dialysance values of a

hemodialyser employed in the hemodialysis treatment procedure. The hemodialysis monitoring equipment of the invention is characterised in that the controller is programmed to relate said one or more entries of said  
5 measured information received by the controller to both a prescribed dialysis dosage reference value and a prescribed weight loss reference value entered into the controller to obtain one or more inter-related values, and to generate one or more output control or command  
10 signals responsive to said one or more inter-related values to automatically control or command one or more operations performed by the hemodialysis monitoring equipment.

15 The nature of the operations performed by the hemodialysis monitoring equipment will depend on the nature of hemodialysis monitoring equipment. However, hemodialysis monitoring equipment of the state of the art will generally comprise means for discontinuing a  
20 hemodialysis treatment procedure after a prescribed treatment time, means for controlling a variable speed ultrafiltration pump in response to a prescribed weight loss and said prescribed treatment time, and means for setting the speed of blood and dialysate pumps. Some

more modern hemodialysis monitoring equipment may comprise means for controlling the composition of dialysate employed in a hemodialysis treatment procedure. Also, some more modern hemodialysis

---

5 monitoring equipment may comprise measuring means comprising conductivity sensors for measuring the conductivity of dialysate upstream and downstream of a hemodialyser product employed in the treatment procedure. The conductivity values (as intermittently  
10 influenced by intermittently introducing small boluses of higher or lower concentration solutions into the dialysis fluid upstream of the hemodialyser) may be employed to reflect instantaneous clearance or dialysance values at various points in time or after  
15 determined time increments, as is for example explained in the above-mentioned Gambro EP0330892. This type of hemodialysis monitoring equipment is preferably employed for providing the measured information employed in controlling variable operations  
20 performed by the hemodialysis monitoring equipment of the invention. However, measured information employed may alternatively be obtained by means of a urea sensor installed on the waste dialysate line which



provides access to real time measure of urea clearance and urea mass transfer.

- 5 An important difference between the invention as described above and approaches followed in the past is that the hemodialysis treatment procedure time involved in the present invention need not be a prescribed time but may be a time which is dependent  
10 on achievement of a prescribed value. Thus, in accordance with the invention, the treatment time may be controlled by measured information which can be related to a measure of an effective clearance value of a substance (usually urea is the reference substance)  
15 measured after a determined time increment during a hemodialysis treatment procedure.

The controller associated with or comprised in the hemodialysis monitoring equipment of the invention  
20 may be programmed to generate output signals reflecting visual actual total dialysis dosages delivered after determined time intervals so that progress of a treatment procedure may be observed. However, more important, and in accordance with the invention, the

controller may be programmed to compute that treatment procedure time which is required to achieve a prescribed total dialysis dosage value. In this case, the controller would be adapted to receive an entry of a

---

5 ~~prescribed total dialysis dosage value and to compute a~~  
hemodialysis treatment procedure time by relating entries of measured information to a prescribed total dialysis dosage value entered into the controller.

- 10 A computed hemodialysis treatment time which is a function of measured information of the above nature will in general be inclined to change during a treatment procedure and would therefore need to be corrected as new entries of measured information are received by
- 15 the controller. The controller may be programmed to compute a total hemodialysis treatment procedure time by integrating over time clearance or dialysance values obtained from measured information measured after determined time increments to obtain a total of the
- 20 dialysis dosage delivered over the effective treatment procedure time which has passed, and computing from this integrated value a total hemodialysis treatment procedure time at which a prescribed total dialysis dosage value would be achieved. Alternately, a

remaining treatment time, which takes into account the total effective dialysis dosage already achieved after a determined time of treatment as compared to a prescribed total dialysis dosage may be computed. This  
5 remaining treatment time may once again need to be corrected as new entries of measured information are received by the controller. This procedure is an approach which is presently preferred.

10 Clearance values are influenced by ultrafiltration which leads to convective transfer of solutes in blood plasma across a semi-permeable membrane of a hemodialyser product into dialysis fluid. In practically all hemodialysis treatment procedures, ultrafiltration to  
15 achieve loss of excess fluid in the patient is required. The controller should therefore be adapted to include or account for the convective clearance which follows from ultrafiltration. Most preferably, therefore, the controller should be adapted to provide output  
20 information related to both the diffusive and convective clearance values or conveniently an integrated measure of these two values.

Ultrafiltration rates are set by setting the speed of a variable speed ultrafiltration pump. The speed of the pump is determined by a prescribed total weight loss value and, in earlier procedures, by a prescribed

5 treatment time. In accordance with the present invention, the controller is adapted to receive an entry of a prescribed total weight loss value and to generate a rate control signal to control the rate of said variable speed ultrafiltration pump as a function of one or more  
10 entries of measured information of the nature described above and both a prescribed dialysis dosage reference value and a prescribed weight loss reference value entered into the controller.

15 By controlling the rate of the ultrafiltration pump as a function of measured information which can be related to diffusive clearance values and including or factoring in the convective clearance value as a function of the diffusive clearance value (which is equivalent to  
20 controlling the rate of the ultrafiltration pump as a function of the diffusive clearance value) it is possible to synchronise advents of achieving a prescribed total clearance or dialysis dosage delivered with achieving a prescribed total weight loss.

In line with an important consideration of the present invention to maintain a controlled relationship between diffusive clearance values and ultrafiltration rate, the  
5 controller may be adapted to compute and maintain a ratio of an ultrafiltration rate to a measured clearance or dialysis dosage value equal or proportional to a ratio of said prescribed total weight loss to said prescribed total clearance or dialysis dosage value.

10

The hemodialysis monitoring equipment of the invention may be associated with or comprise measuring means for obtaining measures of information of the nature described, and entry means for entering such measured  
15 information into the controller. The measuring means may comprise at least a downstream conductivity sensor for measuring the conductivity of dialysate downstream of a hemodialyser device. The measuring means may additionally comprise an upstream  
20 conductivity sensor for measuring the conductivity of dialysate upstream of a hemodialyser device.

Conveniently, the controller is adapted to generate an activating signal when or shortly before the computed.

hemodialysis treatment procedure time is reached. The activating signal may be employed to activate an alert device.

5 ~~Hemodialysis procedure control methods of the~~  
invention correspond to measuring information, relating measured information to prescribed values as described above in relation to the hemodialysis monitoring equipment of the invention, making the computations  
10 and performing the control functions as similarly described.

15

#### DESCRIPTION OF THE DRAWINGS

The invention will be described with reference to the accompanying exemplary drawing tables, wherein:

20 Fig 1 is a schematic drawing of hemodialysis equipment associated with a controller.

Fig 2 is a flow diagram showing various alternative routes which may be followed dependently of measured and prescribed values entered into the controller.

- 5 Fig 3 schematically shows a display screen that would be associated with the controller referred to in Fig 1.

Fig 4 is a flow diagram explaining functions controlled by the controller to set ultrafiltration rate.

10

Fig 5 is a flow diagram of the functions controlled by the controller when a computed remaining hemodialysis treatment time is less than, for example, 15 min.

- 15 Fig 6 is a flow diagram of what occurs if a computed total hemodialysis treatment time exceeds a prescribed maximum treatment time and the routes followed if staff intervention is positive or negative.

- 20 Fig 7 is a flow diagram explaining what attending staff would do and what functions would then be controlled by the controller to set ultrafiltration rate.

#### DETAILED DESCRIPTION

A specific and presently preferred example of blood treatment equipment, associated with or comprising a controller according to the invention, is described

5 below with reference to the accompanying schematic drawing and flow diagrams in which and where employed in the claims, the symbols below will have the meanings identified as follows:

10         $T_t$  = elapsed dialysis treatment time  
          $T_{tr}$  = remaining dialysis treatment time  
          $T_m$  = maximum dialysis treatment time  
          $D_a$  = average dialysance  
          $DT_t$  = dialysance measured at time  $T_t$   
15         $KT$  = dialysis dosage value  
          $KTp$  = prescribed dialysis dosage value  
          $KT_t$  = integrated dialysis dosage value at time  
          $T_t$   
          $WL$  = weight loss  
20         $WL_p$  = prescribed weight loss  
          $WLT_t$  = weight loss at time  $T_t$   
          $UF$  = ultrafiltration rate  
          $UFT_t$  = ultrafiltration rate at time  $T_t$



Referring to the Figure 1 schematic drawing, reference numeral 10 refers generally to a blood treatment equipment, such as for instance hemodialysis equipment, comprising or associated with a controller 5 12, for instance a programmable controller. The equipment is shown to be connected to a blood treatment unit 14, such as a hemodialyser, comprising a blood compartment 16 and a dialysate compartment 18 divided by a semi-permeable membrane 20. A blood 10 pump 22 is provided upstream of the hemodialyzer for pumping blood from a patient along blood arterial line 24 into the blood compartment 16 and out from the blood compartment along blood venous line 26 to drip chamber 28 and back to the patient.

15

Dialysate is conveyed into the dialysate compartment 18 along dialysate inlet line 30 and out from the dialysate compartment along dialysate outlet line 32 in a direction counter-current to blood flow in the 20 hemodialyzer 14. A variable speed ultrafiltration pump 34 is provided for pumping ultrafiltrate from blood comprised in blood compartment 16 across the semi-permeable membrane into the dialysate chamber 18 and out from the dialysate outlet line 32. The flow rate of

dialysate into and out of the dialysate compartment 18 is controlled by conventional means, e.g. by means of flow meters (not shown) located upstream and downstream of the hemodialyzer product or by

5 controlling volumes of dialysate delivered to and withdrawn from the dialysate compartment 18. An infusion line may be provided with (not shown in the appended drawing tables) for injecting replacement fluid in the arterial and/or in the venous line 24,26.

10 The equipment 10 is able to perform different treatments such as:

- conventional hemodialysis, HD, where no infusion is present and dialysis liquid circulates in the second compartment of the dialyzer;
- 15 - hemofiltration, HF, where no dialysis liquid is present while solutes and plasma water are pumped through line 32 and substitution fluid is infused in the extracorporeal circuit or directly into the patient;
- 20 - hemodiafiltration, HDF, which is a combination of HD and HF.

It is of relevance determining, during the treatment, one or more parameters indicative of the progress of the treatment itself in order to intervene actively on the

equipment 10 in view of the desired therapeutic objectives. The controller 12 is therefore designed to calculate a significant parameter indicative of the progress of an extracorporeal blood treatment carried  
5 out by equipment 10. Indicative parameters that can give an indication of the actual progress of a dialysis treatment may be one or more of the following:

- the concentration  $C_b$  of a substance (sodium for instance) in the blood of a patient undergoing a  
10 dialysis treatment;
- the actual dialysance  $DT_t$  or clearance of the blood treatment unit 14 for a specific solute after a time  $T_t$ ;
- the dialysis dose  $KT_t$  after a time  $T_t$ ;
- 15 - any other parameter proportional or known function of one or more of the above three parameters.

European patents number EP 0547025B1 and EP 0658352B1, both herein incorporated by reference,  
20 describe alternative ways for in vivo determination of the actual dialysance, blood sodium concentration and dialysis dose. Note that any method able to determine one or more of the above significant parameters can be used for the purpose of the present invention.

Referring by way of non-limiting example to a first known method for determining the concentration of a substance in blood and/or the actual dialysance for said substance (described in detail in EP 0547025B1),

5 ~~at least two liquids differing for their respective~~  
concentration of said specific substance are sequentially circulated through the dialysate compartment 18.

The first liquid can be the dialysis liquid at its normal  
10 prescribed value of concentration for the substance and the second liquid can be obtained by introducing a step in the concentration of said substance at the dialyzer 14 inlet.

Then the conductivity or concentration of the substance  
15 are measured for the first and second liquid both upstream and downstream of the dialyzer. Note that the upstream measurements can be substituted by set reference values.

Notice in this respect that if the substance is a ionic  
20 substance, then the concentration of the substance influences the conductivity of the dialysis liquid; in particular considering that conductivity is largely influenced by the concentration of sodium ions, than measure/calculation of conductivity values gives an

Indication of sodium concentration in blood and in the dialysis liquid. As conductivity sensors are much more convenient and easy to use than ion selective sensors for directly detecting the concentration of an electrolyte in a liquid flow, conductivity measurements are preferably used.

Referring to figure 1, conductivity or sensors 36 and 38 are provided which are respectively located for measuring the conductivity of dialysate flowing to dialysate compartment 18 along dialysate inlet line 30. In detail, conductivity sensor 36 provides upstream dialysate conductivity measures  $C_{1in}$ ,  $C_{2in}$  relating to the conductivity of the first and second liquid upstream the dialyzer, while conductivity sensor 38 measures the conductivities  $C_{1out}$ ,  $C_{2out}$  of the first and second dialysis liquid flowing from dialysate compartment 18 along dialysate outlet line 32. The measures of conductivity (as intermittently influenced by intermittently introducing small boluses of higher or lower concentration dialysate solutions into the dialysate inlet line 30) may be employed to reflect instantaneous dialysance values at any point in time  $Tt$  during a hemodialysis treatment procedure or after

determined time increments so that a dialysis dosage delivered may be determined.

As a final step the concentration of the substance in blood and/or the the actual dialysance for said

---

5 substance can be obtained from the measured conductivities or concentrations of the substance in the first and second liquid.

In detail the following formulas can be used (no ultrafiltration and neglecting the so-called Donnan  
10 effect):

$$Cd_{out} = Cd_{in} + (C_{bin} - C_{din}) * DTt / Qd$$

Where

$Cd_{out}$  = conductivity (or sodium concentration) of used dialysis liquid downstream dialyzer;

15  $Cd_{in}$  = conductivity (or sodium concentration) of fresh dialysis liquid upstream dialyzer;

$C_{bin}$  = conductivity (or sodium concentration) in untreated blood;

$DTt$  = dialysance for sodium/conductivity measured at  
20 time  $Tt$ ;

$Qd$  = dialysis liquid flow.

$KTt = QTt$  if ultrafiltration is set to 0.

The above equation can be written for the two dialysis liquids circulated through the dialyzer so that the two unknowns  $DT_t$  and  $C_{bin}$  can be determined.

- 5 Referring again to the drawings, the periodically measured conductivity values  $Cd_{1in}$ ,  $Cd_{2in}$  and  $Cd_{1out}$ ,  $Cd_{2out}$  (1 and 2 referring to the first and second liquid respectively) are entered into the controller via lines 40 and 42. The controller can then calculate  $DT_t$  and
- 10  $C_{bin}$  by using for instance the above described method and also estimate the clearance  $K$  and the dialysis dose  $KT_t/V$ , where  $T_t$  is the elapsed treatment time and  $V$  is the total volume of water for the patient.

Prescribed dialysis dosage reference values  $KT_p$  and

15 prescribed total weight loss reference value  $LW_p$  ( $TWL_p$ ) are similarly entered into the controller via entry means 44 of any kind: a data reader, a keyboard, a remote station.

The controller is programmed to perform the

20 calculations or estimations shown, in accordance with estimation or calculation procedures described in detail hereafter or as described in relation to Figures 2, 4 and 7 of the accompanying flow diagrams.

Figure 3 shows a display screen 50 which would be associated with the controller 12 and would provide visual indications of events as shown and information reflected by the controller based on measured

5 information measured during the course of a hemodialysis treatment procedure, as is further explained in conjunction with the flow diagrams of Figures 5, 6 and 7. The display screen also comprises temporary and permanent by-pass buttons 52 and 54  
10 which would be depressed by attending staff if certain events occur, e.g. as explained in relation to the flow diagram of Figure 6. The permanent by-pass button would for example be depressed if a new dialysis treatment setting is to be initiated or if a treatment  
15 procedure is to be discontinued.

Going in further detail, it should be borne in mind that it is an overall objective of the present invention to secure control over the actual total dialysis dosage  
20 delivered to a patient; this control can for example be achieved, in accordance with the invention, by computing a hemodialysis treatment procedure time as a function of calculated values related to one or more of the above identified significant parameters (such as



an effective clearance or dialysis dosage value reached after at treatment time  $t$ ); a basic component of such computation would comprise a determination of a treatment time as a function of such one or more  
5 calulated values. Thus, in this example, a computed total effective treatment time would need to be a function of one or more values  $KTt_1$ ,  $KTt_2$ ,  $KTt_3$ , ...,  $KTt_n$ , calculated in vivo using any known method after determined time increments  $\Delta t =$  say 5 min. For  
10 practical reasons it may only be possible to obtain a first measured value after about say 15 min of effective treatment time. Presuming this to be the case, a reasonably accurate assessment of an initial clearance or dosage value  $KTt_1$  which has been achieved during  
15 said 15 min initial treatment time can be obtained by assuming that the measured clearance value or dosage delivered, for example after a 5 min interval, will substantially equate with the clearance value delivered over the same time period before the first measurement  
20 is made.

Successive measurements of clearance values would generally be at least fractionally different from one another in that these values are dependent on changes

(usually lowering) of the clearance capacity of the dialyser product during a treatment procedure, changes of blood rate, possible recirculation of treated blood, dialysis liquid flow rate, ultrafiltration rate and other

---

5 changes.

Measurements of clearance values would only be made during effective treatment times, i.e. while blood and dialysis liquid are flowing through the hemodialyser product. The controller is accordingly be programmed to initiate measurements only during effective treatment times and similarly only compute or integrate effective treatment times to arrive at a computed hemodialysis treatment procedure time during effective treatment times.

It would be possible to compute a hemodialysis treatment procedure time as a function of measured values in various fashions, e.g. by reference of the difference between successive total dialysis dosage values to a reference difference value and to compute an increase or decrease in the treatment time proportional to deviations from the reference difference value. Such a procedure could for example be realised

more readily if a standardised total clearance or dialysis dosage value is to be achieved. However, a simpler, more adaptable and reliable procedure is to compare measured values with a prescribed total dialysis dosage value specifically prescribed for the particular patient condition. In this fashion the dialysis treatment procedure time at which the prescribed total dialysis dosage value will be reached can be computed. Exemplary of this procedure is the following:

- 10 Before initiating a hemodialysis treatment procedure,
- The total clearance value  $KT$  to be achieved is prescribed ( $KT_p$ ).

Then during the treatment,

- 15
- The effective total dialysis dosage value which has been achieved by a determined effective treatment time  $T_t$  is computed ( $KT_t$ )
  - The remaining treatment procedure time ( $T_{tr}$ ) is computed e.g. based on a computation of the ratio of the difference between the prescribed total clearance value  $KT_p$  and the computed effective total dialysis dosage achieved by time  $T_t$  ( $KT_t$ ) to the instantaneous dialysance value measured at time  $T_t$  ( $DT_t$ ) i.e.  $T_{tr} = \frac{(KT_p - KT_t)}{DT_t}$
- 20

$DT_t$

As mentioned, practically all treatment procedures involve ultrafiltration to achieve a prescribed total weight loss (WLP or TWLP) during the effective treatment procedure time. Since it is most desirable to complete a hemodialysis treatment procedure in as short a time as is possible, the ultrafiltration rate controlled by a variable speed ultrafiltration pump should be set to achieve the prescribed total weight loss WLP within the effective time of the treatment procedure. Accordingly the speed of the ultrafiltration pump may be set to achieve the prescribed total weight loss at a point in time which is earlier, say 20 min earlier, than the time by which the prescribed total clearance KTp might be achieved. Thus, the total time that the ultrafiltration pump is operative may be somewhat less than the effective treatment time during which diffusion of solutes from blood into dialysis fluid, i.e. diffusive clearance, takes place. However, also for the reason that ultrafiltration influences clearance values, it is preferable that the ultrafiltration pump is operative over the same period of time as diffusive clearance of solutes from blood is taking place. With this preference in mind, and in accordance with the

invention, the setting of the speed of the ultrafiltration pump is preferably controlled by the controller in such a fashion that a prescribed total weight loss WLP is achieved at the same time as the prescribed total dialysis dosage value KTp is achieved.

Synchronising an achievement of a prescribed total weight loss WLP with an achievement of a prescribed total dialysis dosage value KTp can be automatically secured by suitable adaption of the controller, for example by relating an actual measured total ultrafiltration volume achieved by time Tt to the prescribed total weight loss WLP, and controlling the rate of the ultrafiltration pump in response to the compared values and the estimated remaining treatment procedure time Tt, referred to above in connection with dialysis dosage values to be achieved. The estimated remaining treatment procedure time is a function of a measured instantaneous dialysance value DTt measured at time Tt, so that the setting of the rate of the ultrafiltration pump will similarly be a function of this instantaneous measured dialysance value. Thus, the ultrafiltration rate at time Tt (UFTt) is set to be equal to the prescribed total weight loss WLP less the

measured weight loss at time  $T_t$ , i.e.  $WLT_t$ , divided by  
the estimated remaining treatment time  $T_{tr}$ , i.e.  $UFT_t =$   
$$\frac{WLP - WLT_t}{T_t}$$

5

The total treatment time  $T$  or remaining treatment time  
 $T_{tr}$  at time  $T_t$  is regularly recalculated and updated on  
the basis of the last or most recent instantaneous  
measured clearance or dialysance value  $DT_t$ . Thus, any  
10 such changes in parameters which take place during a  
hemodialysis treatment procedure which may influence  
the dialysance or clearance of a hemodialyser product,  
such as blood flow rate, dialysis fluid flow rate,  
alterations in the permeability of the semi-permeable  
15 membrane of the hemodialyser product, will  
automatically be accounted for each time the treatment  
time is recalculated. This procedure of the invention  
accordingly provides a reliable means for securing a  
measure of the treatment time required to secure the  
20 prescribed dialysis dosage value  $KTp$ .

As mentioned, the above procedure may also involve  
corresponding control of the rate of ultrafiltration in  
such a fashion that the ultrafiltration rate is also an

Indirect function of instantaneous measured dialysance values by virtue of treatment times being a function of such measured values.

- 5 Measured dialysance values will generally include a measure of convective clearance values obtained by ultrafiltration. An alternative approach to the invention is to maintain a ratio of ultrafiltration rate UF to average dialysance  $D_a$  proportional or equal to a ratio  
10 of a prescribed total weight loss  $W_{Lp}$  to a prescribed total clearance or dialysis dosage value  $K_{Tp}$ , i.e.

$$\frac{UF}{D_a} = \frac{W_{Lp}}{K_{Tp}}$$

$D_a$   $K_{Tp}$

- 15 Since  $W_{Lp}$  and  $K_{Tp}$  are known values  $\frac{W_{Lp}}{K_{Tp}}$  = a known

$K_{Tp}$

- value  $R$ . Thus, at any dialysance measure at the time  $t$ , i.e.  $D_{Tt}$ , the ultrafiltration rate at time  $Tt$ , i.e.  $U_{FTt}$  would be set at  $D_{Tt} \cdot R$ , i.e.  $U_{FTt} = D_{Tt} \cdot R$ . In this  
20 procedure, the effective time of the hemodialysis treatment procedure can be ended when the prescribed total weight loss  $W_{Lp}$  has been achieved. In this case, the prescribed total weight loss can be employed as the over-riding factor in the computation of the

hemodialysis treatment procedure time rather than the prescribed total clearance or dialysis dosage value  $K_{Tp}$ . However, since the above-mentioned known value  $R$  is a ratio of the prescribed total weight loss  $W_{Lp}$  and the prescribed total clearance or dialysis dosage value  $K_{Tp}$ , the  $K_{Tp}$  value will also be at least substantially achieved at the time that the prescribed total weight loss  $W_{Lp}$  is achieved.

- 10 The above alternative approach to the invention may provide a convenient approach in that the ultrafiltration pump may be set at a known speed at the commencement of a hemodialysis treatment procedure and thereafter altered in accordance with the above
- 15  $UFT_t = DT_t \cdot R$  equation. As already mentioned, a first dialysance or clearance measurement can generally only be made after an initial elapse of time of say 15 min, so that only an estimation based on later measurements of what dialysis dosage has been
- 20 delivered during the first 15 min can be made.



## WHAT IS CLAIMED IS:

1. 1. A controller for a blood treatment equipment, said  
equipment comprising at least a treatment unit  
5 including a semipermeable membrane separating the  
treatment unit in a first compartment for the  
circulation of blood and in a second compartment for  
the circulation a of a treatment liquid, the controller  
being adapted to:  
10 receive one or more entries of measured information  
measured during the course of a treatment  
procedure,  
calculate from said measured information at least a  
significant parameter indicative of the progress of an  
15 extracorporeal blood treatment carried out by the  
equipment, characterised in that the controller is  
also adapted to compare said calculated significant  
parameter to a prescribed reference value for the  
same parameter, and to generate at least one output  
20 control signal responsive to said comparison for  
automatically controlling one or more operations  
performed by the equipment.

2. Controller according to claim 1, wherein the prescribed parameter is one chosen in the group comprising:

- the concentration  $C_b$  of a substance in the blood of a patient undergoing a treatment;
- the actual dialysance  $DT_t$  or clearance of a blood treatment unit associated with the equipment for a specific solute after a time  $T_t$ ;
- the dialysis dose  $KT_t$  after a time  $T_t$ ;
- a parameter proportional or known function of one or more of the above three parameters.

3. Controller according to claims 1 or 2, wherein said measured information is one chosen in the group comprising:

- conductivity of the of the treatment liquid downstream the dialyzer;
- concentration of a substance in the treatment liquid downstream the dialyzer.

4. Controller according to claim 1 or 2 or 3, wherein the controller generates the output control signal responsive to said comparison for automatically

controlling a fluid removal rate from said second compartment.

5. Controller according to anyone of claims 1-4  
5 programmed to relate said one or more significant parameters to both a prescribed dialysis dosage reference value and a prescribed weight loss reference value entered into the controller to obtain one or more inter-related values, and to  
10 generate at least one or more output control signals responsive to said one or more inter-related values to automatically control one or more variable operations performed by the equipment.

15

6. Controller according to claim 5, in which said one or more inter-related values comprises a multiplied relationship between said one or more entries of said measured information and a ratio of  
20 a prescribed dialysis dosage value to a prescribed weight loss value or a ratio of a difference between said prescribed dialysis dosage value and a measure of a delivered dialysis dosage to a difference between said prescribed weight loss

value and an achieved weight loss, or the inverse of such ratio as respectively represented by

$$\frac{WLP \cdot DTt}{KTp} \quad \text{or} \quad \frac{(WLP - WLTt) \cdot DTt}{(KTp - KTt)}$$

5 or the inverse of such ratios, wherein the symbols have the meanings identified herein.

10 7. Controller according to claim 4, in which the controller is programmed to compute a total delivered dialysis dosage in response to measured information received by the controller, and to generate an output command signal when said measured information received by the controller reflects a measure of a total delivered dialysis dosage which approximates or equates with said  
15 prescribed dialysis dosage value.

20 8. Controller according to claim 4, in which the controller is programmed to compute a total delivered dialysis dosage at one or more determined time increments during a treatment procedure in response to measured information received by the controller at said one or more determined time increments, and to generate an

output command signal when said measured information received by the controller reflects a measure of a total delivered dialysis dosage which approximates or equates with said prescribed dialysis dosage value.

9. Controller according to claim 4, in which the controller is programmed to compute a hemodialysis treatment procedure time or remaining hemodialysis treatment procedure time by relating a computation of a delivered dialysis dosage reflected by an entry of measured information received by the controller after a determined time increment during a hemodialysis treatment procedure to said prescribed dialysis dosage value.

10. Controller according to claim 9, in which the controller is programmed to:  
determine a plurality of values of said significant parameter, preferably including the dialysis dosage, after a plurality of determined time increments, integrate said plurality of values over said plurality of time increments to reflect an integrated measure

of a total value of said significant parameter delivered, preferably the total delivered dialysis dosage, as related to an integral or total of said plurality of determined time increments.

5

11. Controller according to claim 9, in which the controller is programmed to compute a remaining treatment procedure time by subtracting said measure of a delivered dialysis dosage from said prescribed dialysis dosage value and dividing the resulting difference by an average dialysance value represented by said delivered dialysis dosage divided by said determined time increment.

10

12. Controller according to claim 9, in which the controller is programmed to compute a remaining treatment procedure time by subtracting said measure of a delivered dialysis dosage from said prescribed dialysis dosage value and dividing the resulting difference by an instantaneous dialysance value measured at the end of said determined time increment, as represented by  $(K_{Tp} - K_{Tt}) / DT_t$ .

15

20

13. Controller according to claim 4, wherein the equipment includes a variable speed ultrafiltration pump, said one or more output control signals responsive to said one or more inter-related values generated by the controller are employed to automatically control the speed of said variable speed ultrafiltration pump.

14. Controller according to claim 12, in which said one or more inter-related values comprises a multiplied relationship between said one or more entries of said measured information and a ratio of a prescribed dialysis dosage value to a prescribed weight loss value or a ratio of a difference between said prescribed dialysis dosage value and a measure of a delivered dialysis dosage to a difference between said prescribed weight loss value and an achieved weight loss, or the inverse of such ratio as respectively represented by

$$\frac{WLP \cdot DTt}{KTP} \quad \text{or} \quad \frac{(WLP - WLTt) \cdot DTt}{(KTP - KTt_r)} \quad \text{or the}$$

inverse of such ratios, wherein the symbols have the meanings identified herein.

15. Controller according to claim 14, in which the controller is programmed to generate a control signal responsive to said multiplied relationship to automatically control the speed of said variable speed ultrafiltration pump to maintain said ratio or inverse thereof, whereby the entered prescribed total weight loss reference value may be achieved substantially simultaneously with delivery of the entered prescribed dialysis dosage reference value.

16. Controller according to claim 13, in which the controller is programmed to reflect a measure of a total weight loss achieved as a function of the speed of the variable speed ultrafiltration pump and a determined time increment during a hemodialysis treatment procedure.

17. Controller according to claim 9, the equipment including a variable speed ultrafiltration pump, in which the controller is programmed to generate a control signal to automatically control the speed of said variable



speed ultrafiltration pump as a function said  
computed treatment procedure time or remaining  
treatment procedure time and said prescribed  
weight loss reference value entered into the  
5 controller.

2. 18. Blood treatment equipment comprising at least a  
treatment unit including a semipermeable membrane  
separating the treatment unit in a first compartment  
10 for the circulation of blood and in a second  
compartment for the circulation a of a treatment  
liquid, and a controller according to anyone of the  
preceding claims.

3.

- 415 19. Equipment according to claim 18 comprising  
measuring means for obtaining one or more  
measures of information during the course of a  
hemodialysis procedure, which information can  
reflect one or more measures of dialysis dosage  
20 values or dialysance values of said treatment unit,  
this latter including a hemodialyser, the equipment  
also including entry means for entering such  
measured information into the controller.

5.

6. 20. Equipment according to claim 19, in which the measuring means comprises a downstream conductivity sensor for measuring the conductivity of dialysate in a dialysate line downstream of the treatment unit.

21. Equipment according to claim 19, in which the measuring means additionally comprises an upstream conductivity sensor for measuring the conductivity of dialysate in a dialysate line upstream of the treatment unit.

22. Equipment according to claim 19, in which the controller is programmed to reflect one or more dialysance values of said hemodialyser at one or more determined time increments during a hemodialysis treatment procedure and to compute a hemodialysis treatment procedure time or remaining hemodialysis treatment procedure time by relating such dialysance values and determined time increments to said prescribed dialysis dosage reference value entered into the controller.

23. Equipment according to claim 22, comprising a variable speed ultrafiltration pump, in which the controller is programmed to generate a control signal to automatically control the speed of the variable speed ultrafiltration pump as a function said computed hemodialysis treatment procedure time or remaining hemodialysis treatment procedure time and said prescribed weight loss reference value entered into the controller.

24. Equipment according to claim 22, in which a prescribed maximum hemodialysis treatment procedure time is entered into the controller and in which the controller is programmed to compare said computed hemodialysis treatment time or remaining hemodialysis treatment time with said prescribed maximum hemodialysis treatment procedure time and, if a total computed hemodialysis treatment time exceeds said prescribed maximum treatment time, to generate an output control signal to control the speed of the ultrafiltration pump to achieve said prescribed weight loss reference value when said prescribed maximum hemodialysis treatment time is reached.

25.Equipment according to claim 20, in which the controller is associated with an alert device, in which a prescribed maximum hemodialysis treatment procedure time is entered into the controller and in which the controller is

5

programmed to compare said computed hemodialysis treatment procedure time or remaining hemodialysis treatment time with said prescribed maximum hemodialysis treatment procedure time and, if a total computed hemodialysis treatment time exceeds said entered prescribed maximum treatment time, to generate a command signal to activate said alert device.

10

26.Equipment according to claim 18, in which the controller is associated with a display screen adapted to display an output signal from the controller reflecting said measures of delivered dialysis dosages or dialysance values of a hemodialyser reflected by said measured information.

15

20

27.Equipment according to claim 18, in which the controller is associated with a display screen adapted to display an output signal from the controller reflecting said total delivered dialysis

dosage reflected in response to measured information received by the controller.

28. Equipment according to claim 18, in which the controller is associated with a display screen adapted to display an output signal from the controller reflecting said total delivered dialysis dosage reflected in response to measured information received by the controller.

29. Equipment according to claim 18, in which the controller is associated with a display screen adapted to display an output signal from the controller reflecting said hemodialysis treatment time or remaining hemodialysis treatment time computed by the controller.

30. Equipment according to claim 18, in which the controller is associated with a display screen adapted to display said prescribed dialysis dosage reference value entered into the controller.

31. Equipment according to claim 18, in which the controller is associated with a display screen adapted to display said prescribed weight loss reference value entered into the controller.

32. Equipment according to claim 18, in which the controller is associated with a display screen adapted to display said measure of a total weight loss achieved.

5 33. Equipment according to claim 18, in which the controller is associated with a display screen adapted to display said prescribed maximum hemodialysis treatment procedure time entered into the controller.

10 34. A method of automatically controlling one or more variable operations performed by hemodialysis monitoring equipment associated with or comprising a programmable controller adapted to receive entries of prescribed and measured  
15 information and to generate one or more output signals in response thereto, which comprises the steps of securing one or more measurements of information during the course of a hemodialysis treatment procedure, which measured information  
20 can be employed to reflect a measure of a delivered dialysis dosage or a dialysance value of a hemodialyser employed in such hemodialysis treatment procedure, entering said measured information into the controller, entering both a

prescribed dialysis dosage reference value and a prescribed weight loss reference value into the controller, relating said measured information to said prescribed reference values to obtain one or more inter-related values, and employing said inter-related values to generate one or more output control signals responsive to said inter-related values to automatically control one or more variable operations performed by said hemodialysis monitoring equipment.

35.A method according to claim 34, in which the measured information secured comprises one or measures of urea clearance, measured during the course of a hemodialysis treatment procedure.

36.A method according to claim 34, in which the measured information is secured by performing measurements of the conductivity of dialysate downstream of a hemodialyser employed in said hemodialysis treatment procedure following on introducing one or more boluses of high or low concentration dialysate solutions into the dialysate upstream of the hemodialyser.

37.A method according to claim 34, in which the one or more inter-related values are

$WLp \cdot DTt$

$KTp$

or

5  $(WLp - WLTt) \cdot DTt,$

$KTp - KTr,$

wherein the symbols have the meanings identified herein.

10 38.A method according to claim 34, in which either of said inter-related values are employed to control the speed of a variable speed ultrafiltration pump so that the ultrafiltration rate equates with said inter-related value, whereby the entered prescribed total weight loss reference value  
15 maybe achieved substantially simultaneously with delivery of the entered prescribed dialysis dosage reference value.

20 39.A method according to claim 34, in which said measured information entered into the controller as related to said prescribed reference values are employed to compute a hemodialysis treatment procedure time or remaining hemodialysis treatment procedure time by relating a measure of a delivered dialysis dosage reflected by an entry



of measured information received by the controller after a determined time increment during a hemodialysis treatment procedure to said prescribed dialysis dosage value.

5 40. Program storage means including a program for a programmable controller according to the preceding claims, the program when run by the controller rendering the controller adapted to execute a control method according to the  
10 preceding claims.

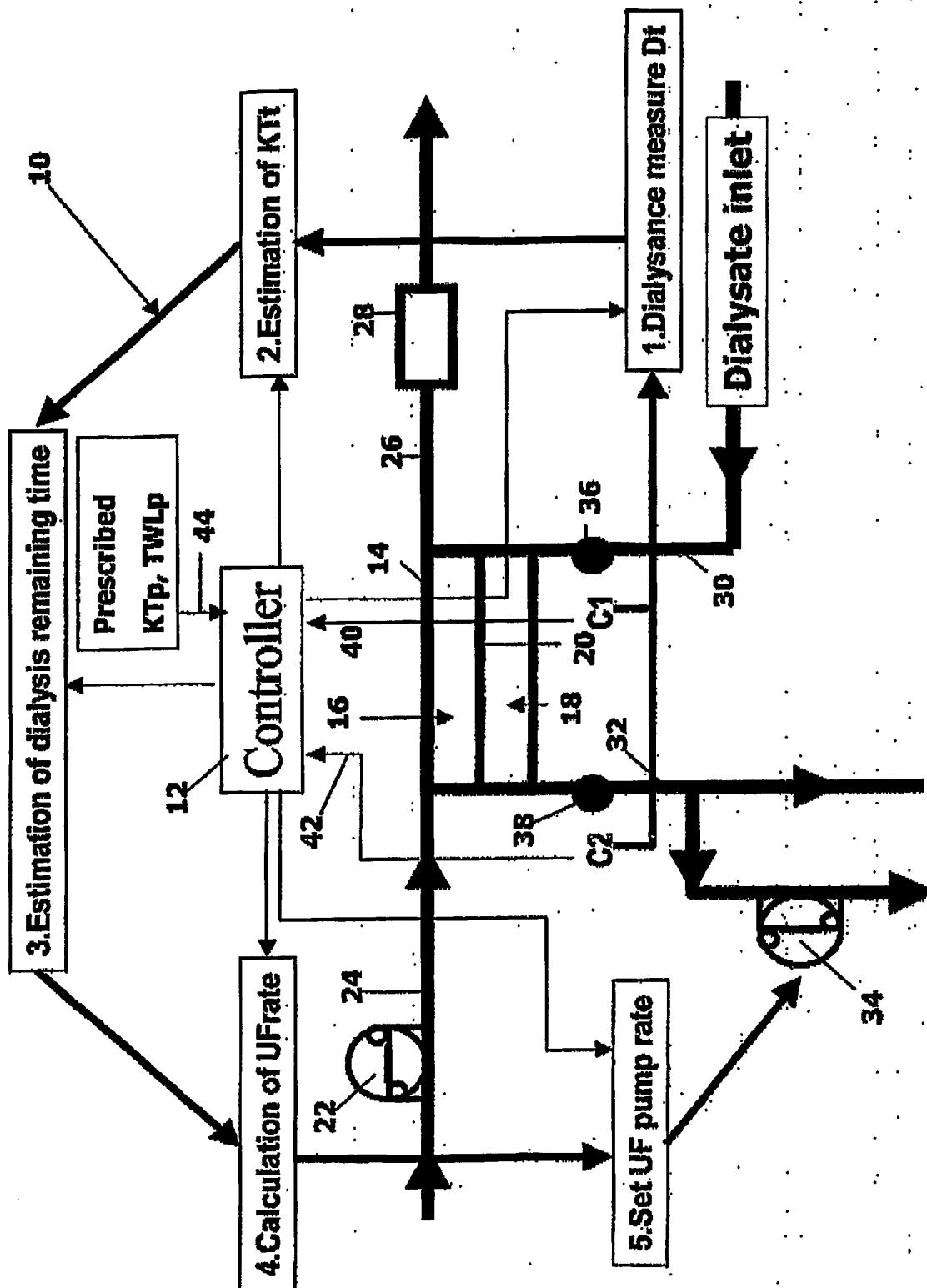
41. Program storage means according to claim 40 comprising an optical data carrier and/or a magnetic data carrier and or a volatile memory support.

15

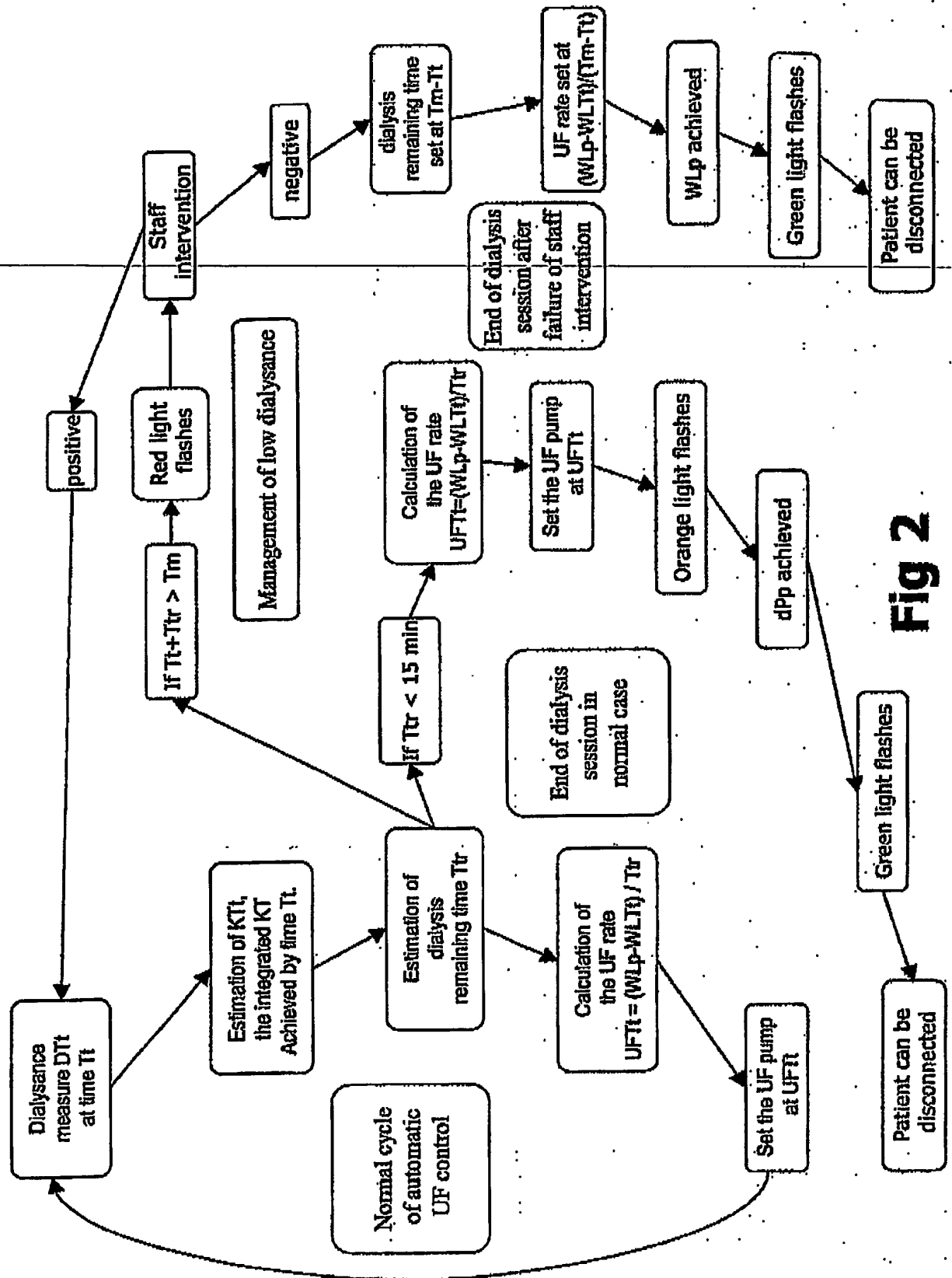
20

**ABSTRACT OF THE DISCLOSURE**

Disclosed is a blood treatment equipment which is associated with or comprises a programmable controller adapted to receive entries of prescribed and measured information and to generate one or more control signals in response thereto. The equipment is characterised in that the controller is programmed to relate entries of measured information to prescribed dialysis dosage and weight loss value. Also disclosed are corresponding methods and program storage media.

**Fig 1**

# Dialysis delivery control overview



**Fig 2**

# Dialysis delivery control User interface

50

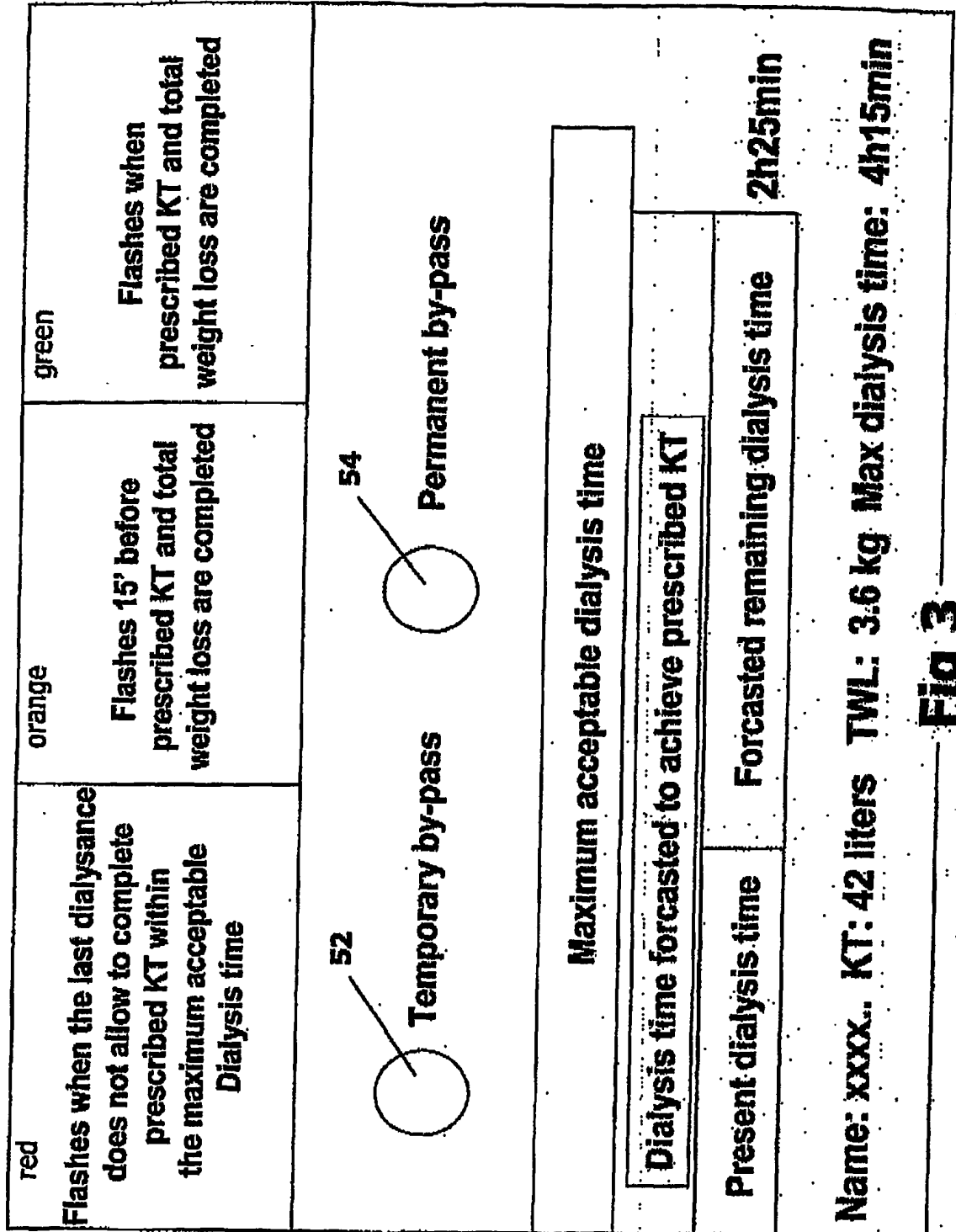


Fig 3

## Normal cycle of automatic UF control

Before the start of the session, total weight loss (TWLp), KT to be achieved (KTp), and the maximum acceptable dialysis time (Tm) are entered by the doctor.

During the session, at any time t:

Dialysance measure based on conductivity measures by probes c1 and c2 at dialysate inlet and dialysate outlet. (1)  
(see Fig1)

Estimation of KTt, the integrated KT achieved up to time t. (2)

Estimation of dialysis remaining time Ttr, necessary to achieve prescribed KTp: (3)

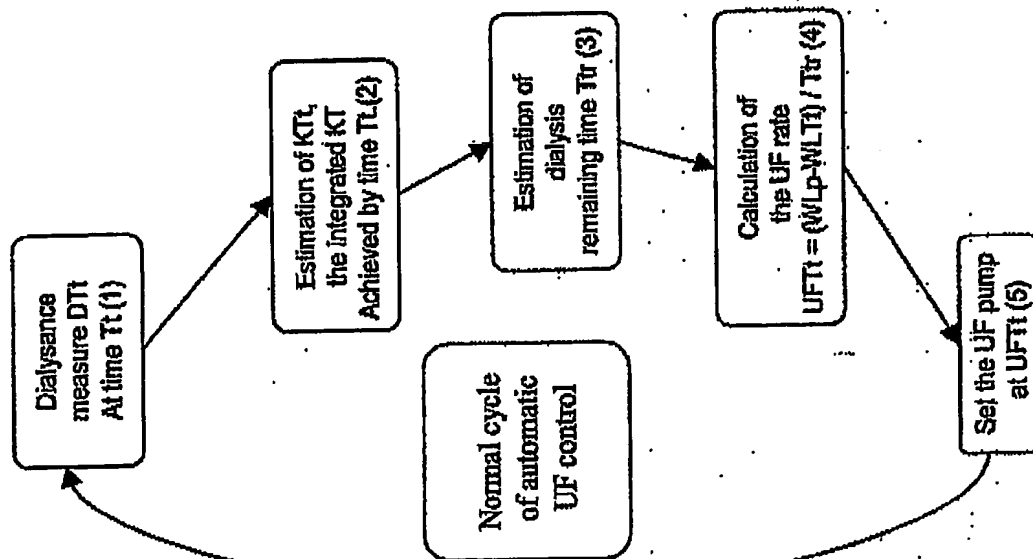
$$T_{tr} = (K_{Tp} - K_{Tt}) / D_{Tt}$$

Calculation of the UF rate needed to achieve the total weight loss during the remaining time Ttr (4)

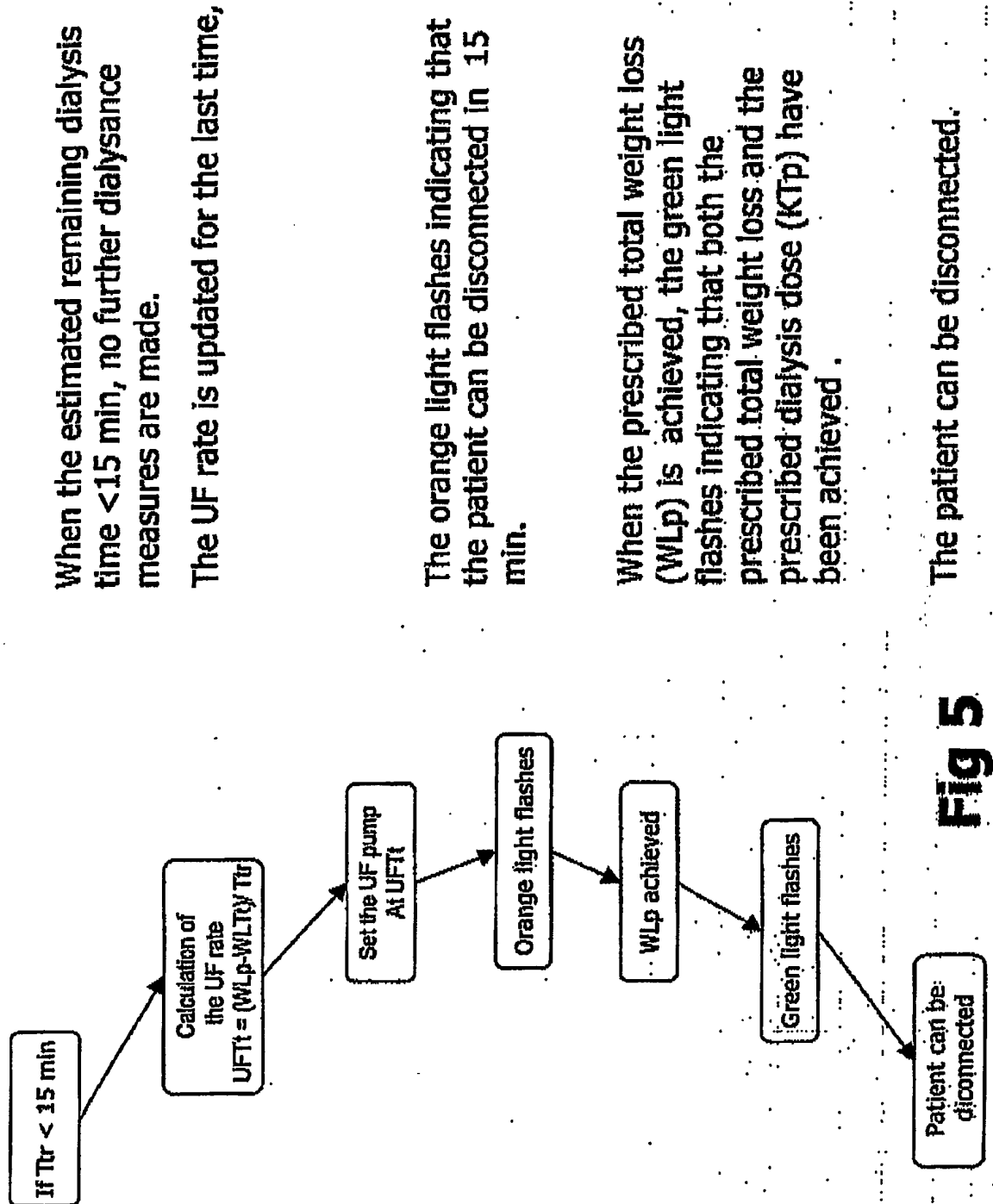
$$UFTt = (WLP - WL_{Tt}) / T_{tr}$$

Set the UF pump at UFTt (5)

**Fig 4**

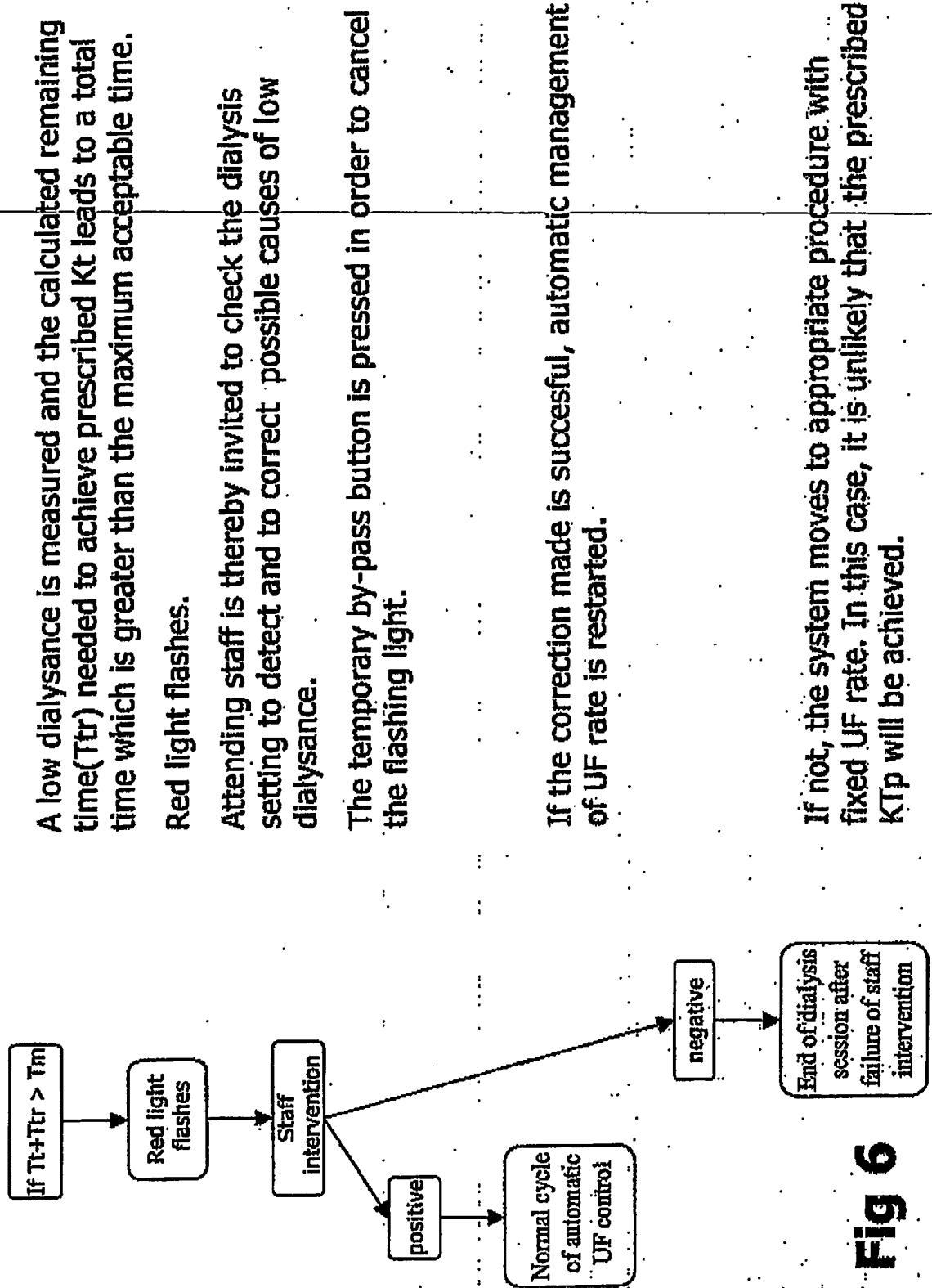


## End of dialysis session in normal case



**Fig 5**

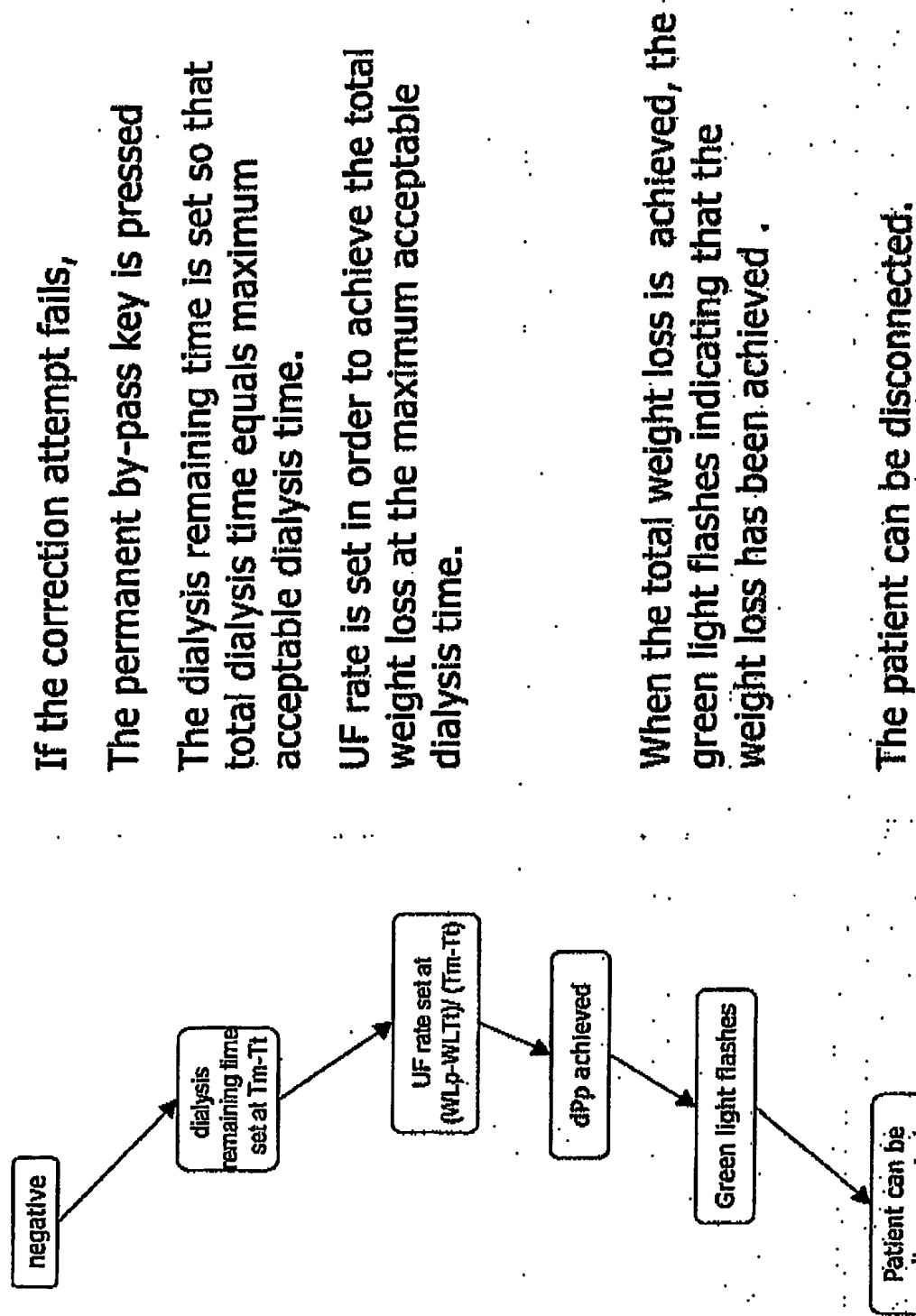
## Management of low dialysance



**Fig 6**



## End of dialysis session after failure of staff intervention



**Fig 7**

**This Page is Inserted by IFW Indexing and Scanning  
Operations and is not part of the Official Record**

**BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☐ FADED TEXT OR DRAWING
- ☐ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☐ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☒ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☒ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: \_\_\_\_\_

**IMAGES ARE BEST AVAILABLE COPY.**

**As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.**